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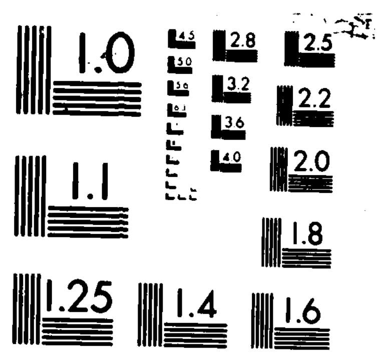

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AIR WAR COLLEGE

RESEARCH REPORT

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THE BEST INVESTMENT FOR THE AIR SUPERIORITY FIGHTER OF THE YEAR 2000: THE AIRCRAFT, ITS WEAPON SYSTEM OR ITS ARMAMENT?

By COLONEL JEAN-GEORGES BREVOT, FRENCH AIR FORCE

AIR UNIVERSITY
UNITED STATES AIR FORCE
MAXWELL AIR FORCE BASE, ALABAMA

AIR WAR COLLEGE

AIR UNIVERSITY

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Jean-Georges Brevot

Colonel, French Air Force

A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE RESEARCH

REQUIREMENT

Research Advisor: Colonel Douglas S. Hawkins

MAXWELL AIR FORCE BASE, ALABAMA

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AIR WAR COLLEGE RESEARCH REPORT ABSTRACT

TITLE: The best investment for the air superiority fighter of the year 2000: the aircraft, its weapon system or its armament?

AUTHOR: Jean-Georges Brevot, Colonel, French Air Force

Assuming that the cost rising problem and the budget constraints will compel the planners to important trade-offs in the air superiority fighter programs for the year 2000, the author tries to determine which research and development investments will be the most productive for the mission effectiveness. After studying the threat, growing both in quantity and quality, he analyses the characteristics of modern air combat and the current technology trends. Looking forward to the future, he draws the new reqirements and then advocates for the good priorities in the investments to come.

BIOGRAPHICAL SKETCH

Colonel Jean-Georges Brevot attended the French Air Force Academy at Salon-de Provence and was commissioned in 1966. After attending fighter pilot training school at Tours and Cazaux AFB, he was in 1968 an F-100 Super Sabre pilot in the 11th Wing at Toul AFB. Then for six years, he was a Mirage IIIE pilot in the 13th Wing at Colmar AFB where he ended as a flight commander. From 1975 to 1977 he was responsible for the development and the military experimentation of the dogfight air-to-air MAGIC missile in the Centre d' Experiences Aeriennes Militaires (CEAM) at Mont-de-Marsan AFB. Then for three years he was assigned at Orange AFB as the Commander of the 1st Squadron of the 5th Wing on Mirage F1. From 1980 to 1983, he was responsible for the development and military experimentation of the Mirage 2000 (air defense role) at Istres and Mont-de-Marsan AFB, flying the early prototypes and then the serial aircraft. During his last two years he was the Commander of the Aircraft Division of the CEAM, flying all the new aircraft of the French Air Force. Colonel Brevot is a graduate of the Air War College, class of 1986.

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1- INTRODUCTION

1.1- The battle of the Bekaa Valley

In 1983, during the conflict between Israel and Syria for control of the Bekaa Valley in Lebanon, occured probably one of the most significant events in modern aerial warfare. In one day of air combat the Israeli Air Force destroyed 90 Syrian fighter aircraft without any single loss.

The reason of this exceptional success: a technological gap in favor of Israel, gap of which the Israeli Air Force made the most with excellent tactical concepts and skills.

The tools brought by this technological gap were:

-pulse doppler radars on all the modern Israeli fighters (F15 and F16) allowing long range detection at all altitudes, including the very low ones.

-very effective all aspects air-to-air missiles either electro-magnetic (EM) like the SPARROW AIM 7F or infra-red (IR) like the SIDEWINDER AIM 9L.

-airborne warning radars (E2C HAWKEYE) coupled with an effective Command Control Communications and Information (C3I) system giving to the Israeli command the necessary situation awareness.

-advanced airborne electronic warfare (EW) systems on all the aircraft.

As a result it was impossible for the Syrian Air Force, equipped with fighters and air-to-air missiles of the 60's (MIG 21, MIG 23, AA2 ATOLL) without any EW system, to win this fight.The Syrian aircraft, detected from take off,monitored and engaged early by the Israelis, were destroyed without any possible defense. Half of them were killed at long distance by the AIM 7F's launched by the F 15.Most of the remaining aircraft were killed at shorter distance by the AIM 9L's launched by the F 15 and F 16.A handful of them were killed by the guns of these highly maneuverable fighters.

The lesson is very clear: if you have no real advantage in tactics and experience, a technological gap is unacceptable; you cannot afford a war if you are one generation late in your materials when comparing to the enemy.

1.2- <u>The cost rising problem</u>

The cost rising associated with the application of emerging technologies to the new materials is truly frightening.

This rising is not only a matter of paying the price of new improvements. The secondary effect of a higher unit cost due to the technology is that the Air Force buys fewer materials so the production rate decreases. As a result the unit price rises again, the number purchased by the Air Force decreases again and so on. It is a kind of vicious circle.

In the current reform movement debate, it is difficult to evaluate the rate of Air Force materials cost rising because a lot of confusion is brought by the debaters: comparison of

materials designed for different missions, comparison of cost with different production rates, various methods of price calculation.

Nevertheless we can say that, roughly speaking and in constant dollars, the unit price of a fighter aircraft increases two to three times between two generations (15 to 20 years).And the current tendancy is to an augmentation of this rate. (1)

When considering the corresponding much lower rate of the Defense budget, it appears that obviously there is a limit. Dr Norman Augustine, Chairman of DOD's Defense Science Board, predicted that in the year 2054 the entire US Defense budget will purchase just one tactical aircraft...(2)

These considerations are the bases of the highly controversial quality-quantity debate, but anyway it is certain now that the Air Force planners of every industrialized countries will have to make tough choices for the future materials.

1.3-The driving concept of air superiority

One of the solutions to minimize the cost rising is to try to have the same aircraft (or at least the same airframe with different equipments) to do several missions as different as air superiority, air defense, deep interdiction or close air support. This is the concept of the multirole aircraft where you have only one type of aircraft, thus increasing the number of aircraft ordered by the Air Force and decreasing the cost per unit.

This solution is now possible without too many compromises because of two technological improvements:

-the "fly-by-wire" technics allowing the same handling qualities and the best performances whatever the configuration of the aircraft.

-the digital airborne computers, more and more powerful, which can be reconfigured by changing the programs according to the mission.

All the contries are now considering the multirole aircraft with interest. When studying the requirements for the different missions, it appears that the air superiority mission is the most demanding one in the field of technology improvement. In other words, a good air superiority fighter with modern technology can carry out the other tacair missions with sufficient effectiveness.

This is the reason why we will basically study in this paper the choices affecting the definition of future air superiority fighters.

1.4-The question

When looking to the issues addressed in the previous pages, we understand that on the one hand it is essential to secure a technological advantage on the potential enemies but on the other hand we cannot buy all the available technology improvements because of budget constraints.

Basically these improvements for the air superiority fighter of the year 2000 (i.e.the fighter coming to initial operating capability in the 90's) can affect three different fields:

- the aircraft,

- its weapon system,
- its armement.

So the question is:

What field is the best investment for the future ?

In other words , what is the most effective : one dollar of aircraft improvement , one dollar of weapon system improvement, or one dollar of armament improvement ?

In the following pages we will study the threat and the environment , the characteristics of the modern combat , the requirement for the future , the cost problems and then we will try to answer the question of the best investment .

2. THE THREAT OF THE 90's . THE ENVIRONMENT

2.1 Soviet quantity vs Western quality

The two potential adversaries , the Warsaw pact forces and the Western countries , have always had totally contrary armament concepts , at least for the conventional armaments .

The Soviet strategy is based upon a massive employment of great quantities of weapons built without a specific emphasis on technology.This concept fits very well with the armament industry of the country, significantly funded (14% of the GNP to the military) and state operated. This industry is able to carry out a mass production, but there are no real incentives to develop high technologies.

The Western countries have armament industries which are sometimes state sponsored, but basically they are privately operated in a competitive environment. The incentives and stakes (profits for the companies, rewards for the brilliant ingeneers) are high enough to generate a permanent technology boom. But the quantities are limited by the costs and the funds (7% of GNP to the military in the US, 4% in France).

These facts have two important consequences:

-The Soviet reliance on quantity led to a numerical Warsaw pact forces advantage over the NATO forces in a ratio of 2 to 1 for the fighter aircraft (and in a ratio of 4 to 1 when comparing the number of Warsaw pact attack aircraft to the number of NATO defense aircraft). (3)

-The Western reliance on quality led to an estimated technological gap of 10 years in favor of the US and its industrialized allies. It is assumed that this technological superiority is able to cope with the numerical disadvantage.

But the trend of the last past years is quite disturbing because many analysts point out that the technology gap is filling up for three main reasons:

-The Soviet industrial intelligence and spying seem to be very effective, and the uncontrolled technology transfers bring sometimes sensitive technical informations to Soviet Union.

-The Soviet leaders, aware of their weakness in the technological field, have emphasized the research and development efforts.

-At the same time, the Western industrialized nations, facing budget constraints, have very often cut significant parts

of their research and development budgets in an attempt to save some important programs.

It is often stated that the Western technology lead is now reduced to 5 years, at least in several fields, and that it could be reduced to nothing in the year 2000.

This situation would be unacceptable considering that the Soviet Union can at the same moment maintain her numerical advantage. With the fielding of the new Soviet fighter aircraft (SU 27, MIG 29, MIG 31) the NATO forces will probably have to face a problem of both quality and quantity in the 90's.

2.2-The Soviet pilot

Because of the characteristics of the communist military society based on a permanent political control, the Soviet pilot has always had the reputation of being too academic and lacking initiative.

But here again things are changing.

The Soviet Air Force leaders are well aware of the quality of the realistic USAF training which tries to develop in the pilot mind a sense of flexibility and adaptability when confronted to a complex and hostile environment. And also they begin to understand that a modern aircraft, with a computerized weapon system giving to the pilot all the necessary informations, requires a pilot acting with initiative.

So we can see a slow but real evolution of the pilot training in Soviet Air Force. Of course this is not to the point of

building Air Combat Maneuvering Ranges (ACMR) or organizing Red Flags, but the Soviet pilot is able to demonstrate more and more initiative.

We can expect a tougher adversary in that field for the 90's.

2.3-The foreseeable types of wars

The Falklands war, which was a complete surprise for the British armed forces, is a good demonstration that it is very difficult to anticipate the type of the next war you will have to wage. In fact the range of possible types of wars for the 90's is very wide.

However we can analyze two types of war which are most likely to be those of the future, even if the probability of occurence is low for the first one and high for the second one.

2.3.1-High intensity warfare in Europe

This is a type of war with a highly complex and hostile environment for the fighter aircraft. The emphasis must be put on survival, multi-aircraft engagements and coordination.

The surface-to-air missiles (SAM) threat is deadly because of the density of the sites and the effectiveness of the new Soviet SAM's. So the suppression of enemy air defenses (SEAD) and the electronic counter-mesures are a must.

To try to gain the air superiority in a conventional war in Europe you have to focus on attacking the enemy airfields. And the best moment for that is when the Warsau pact fighters and

fighter-bombers are coming back to their bases, landing and taxiing.

So a good strategy for counter-air in Europe could be, when the Warsau pact air forces launch their first attack, to tightly and successively coordinate the subsequent operations:

-a strong air defense with the best possible kill ratio to limit the effect of the attack and raise the enemy attrition.

-at the same time, SEAD operations to open the ways to the enemy airfields.

-as soon as these ways are cleared and when the enemy aircraft are returning to their bases, a coordinated attack on the Warsau pact airfields carried out by aircraft which were waiting in air refueling.

The US Advanced Technology Fighter (ATF) will be designed primarily for the air superiority mission in the European theater of operations of the 90's. In that respect the managers of the program emphasize the following characteristics: (4)

-Survivability on the red side of the FEBA

-To get in and take care of the new threats (SU 27, MIG 29, MIG 31, AA 9 and AA 10 missiles)

-First look/ first kill capability against these threats

-To acquire, identify and destroy BVR

-Excellent performances in supersonic cruise and maneuvers, and in accelerations

-Reduction of radar and IR cross sections

-Long combat radius without external tanks

-Excellent supportability generating a high sortie rate through self-sufficiency and a reduced level of maintenance.

2.3.2.Limited wars

One of the main characteristics of the limited wars is that, very often and for political reasons ,the government defines sanctuaries where the enemy air forces cannot be engaged or attacked.And frequently the enemy airfields are sanctuaries.

Consequently the air superiority must be gained by air-to-air combats, with emphasis on early airborne radar detection, endurance, long range operations and air refueling.

2.4.-Joint operations

One of the main characteristics of the modern military operations is that in most cases they involve joint forces.The theater of operations becomes incredibly complex and the biggest efforts must be made to coordinate all the assets.

At the beginning the C3I systems had a tendancy to overcentralize the informations and the decisions. A new concept assumes that, by linking all the assets together so that each of them will have a clear picture of the surrounding situation, the decisions could be taken at a lower level and all the assets would have better results. This is the total force integration concept.

In that respect the JTIDS (Joint tactical information and distribution system) is typical. Basically it is a giant digital communication network linking together all the elements of a given theater of operations.This system is now in production and fielding in the USAF. In France a similar system (compatible with the JTIDS) is in development but no decision has been taken.

The weapon system of each modern fighter involved in operations will be designed to process the JTIDS data. The pilot will have a display presenting the surrounding tactical situation.

2.5-The targets

The air superiority fighter of the year 2000 will have a wide range of possible targets, all different in their mission, size shape and flight elements (altitude, speed, maneuverability).

They are, by order of priority: (5)

1- bombers, ground-attack aircraft, cruise missiles.

2- AWACS, fighter escorts, air superiority fighters, high flying recce, stand-off jammers.

3- tankers, transport, armed helicopters, RPVs.

But the fighter and its weapon system must be tailored to counter the most dangerous threat for it (and also the most probable): the enemy air superiority fighters.

3.- CHARACTERISTICS OF THE MODERN AIR COMBAT. CURRENT TECHNOLOGY TRENDS

3.1-"Fly-by-wire" aircraft

The flu-by-wire technology has two essential consequences in a combat: the high maneuverability of the aircraft and the increased "thinking time" allowed to the pilot.

The maneuverability of a fly-by-wire aircraft is really outstanding. This is due to the fact that this technology allows to fly an aircraft which has an unstable aerodynamic. Such an

aircraft would have been impossible to pilot with conventional controls (man reaction time longer than the delay required to counter the effects of instability, thus creating divergent movements). The stability of the aircraft is permanently retrieved by the computer giving orders to the controls, enabling what is called an "artificial stability". And the pilot flies the aircraft through the computer.

The advantage is that an aircraft with an unstable aerodynamic has a tremendous maneuverability (this is a flight mechanics physical law). The result is that the aircraft of the fly-by-wire generation (F16, F18, MIRAGE 2000) have turning performances reaching levels which were unattainable before: 9G's of lateral acceleration and more than 20 deg/sec of turn rate.

The other essential consequence of the fly-by-wire technology is fully perceived only by the pilots who fly this type of aircraft. Indeed they find quickly that the aircraft is easy to pilot because:

- the controls are very effective and accurate; the aircraft does exactly what the pilot wants without any contrary secondary effect (these effects are " rubbed out " by the controls' computer).

-it is not possible to over-G or to depart the aircraft (the controls' computer has built-in protections against excessive orders from the pilot), so it is practicable to fly the aircraft without any piloting restraint.

The result is that even an unexperienced pilot is able to do the most difficult and effective maneuvers without any specific skilfulness.

But more important is the fact that the mind of the pilot is free from continuously thinking to piloting tricks. In other words, the pilot has much more time to think of what is really important for the mission success: operating the weapon system, situation awareness and assessment, tactics, patrol coordination.

As often stated by the air combat experts of the aggressor squadrons: " When the materials and the training experience are at the same level between adversaries, the one who wins in aerial combat is the one who demonstrates more real thinking time than the others ". (6)

So this consequence is a truly big advantage brought by the fly-by wire technology.

And now that the pilot have an increased "thinking time" in air combat, they must have something to think about....It means that it is essential in modern air combat to develop new tactics and to train the pilots to practice them. In that respect the study simulators, the training simulators and the ACMR are absolutely necessary.

3.2-Air-to-air missiles

One of the most meaningful trends in air combat technology is the exceptional effectiveness of the modern air-to-air (AA) missiles.

From the outset of the guided missiles technology, which was in the 50's, and till the mid-70's, the AA missiles were not considered as being a dangerous threat for the fighter aircraft. These missiles (SIDEWINDER AIM 9B, FALCON AIM 4, MATRA 511 and 530, ATOLL) were easy to avoid by maneuvers or to deceive with jamming, chaffs or IR lures. During the Viet-Nam war it was frequent to see a US fighter launching between 4 to 8 missiles... to try to kill a single MIG.

In the mid-70's and the 80's appeared several AA missiles of the new generation:

- long and medium ranges interception type (with EM seekers): improved SPARROW (AIM 7E, F and M), MATRA SUPER 530, AIM 54 PHOENIX, SKYFLASH, ASPIDE.

- short range and dogfight type (with IR seekers): improved SIDEWINDER (AIM 9L, M and P), MATRA MAGIC, SHAFRIR, PYTHON 3, KUKRI.

These new missiles are very effective (kill probability often better that 0,9 even against a maneuvering or jamming target) for several reasons:

- the "proportional navigation" guidance have been improved thanks to the development of very accurate study simulations.

- weight reduction and improved aerodynamics (e.g. the double canard surface controls of the MAGIC) have given high maneuverability to the missiles.

- as a result of these two improvments, it is now nearly impossible to avoid a modern missile only by maneuvers (even brutal); for instance a MAGIC is able to kill a target turning (and reversing the turns) at more than 10G's.

- improvements in the proximity fuzes and the warheads have dramatically increased the kill probability ratios.

- EM seekers are now equipped with electronic counter counter measures (ECCM) and are hard to jam (MATRA S 530, PHOENIX); the development of the IR multi-sensors seekers (MAGIC 2) has brought a good protection against the lures.

- the development of the IR all aspect capability (AIM 9L, MAGIC 2) has given to the IR missiles a tremendous effectiveness.

The trends for the future are in three fields:

- again increased maneuverability through new concepts: instable aerodynamics, thrust vectoring and high angle of attack control.

- launch and leave capability: already existing for the IR missiles, and in development for the EM missiles with the inertial/active seeker guidance.

- important improvements in the IR seekers technology (IR mozaic, signal processing) which will give them an extreme sensibility without any natural or artificial (i.e. coming from lures) false alarm.

So the future for the AA missiles is very bright.The EM missiles effectiveness will be still linked to the result of the fight between the enemy ECM and its own ECCM, but it is now certain that the all aspect IR missiles will be <u>the essential lethal threat</u> for the fighter aircraft of the 90's. These missiles will be very agile, highly sensitive and accurate, extremely difficult to lure, in short: deadly effective... (7)

3.3- Survival through low level flight

During two decades (the 60's and the 70's) it was commonly assumed in the fighter pilots community that flying at very low level and high speed was the best tactic to provide survival and surprise. Indeed, by doing so, the aircraft were able to make their way below the opposing ground based radar coverage. And moreover they could not be detected by the airborne radars of the enemy fighters because these radars, when looking down, were blinded by the ground clutter.

As a result, the low flying aircraft:

- could not be detected and monitored by the air defense network,

- could not be intercepted by the air defense fighters,

- could not be fired upon by the SAM"s because of a too short reaction time caused by late detection and high speed.

But now things are changing and low level flight is no longer a protection because of the advent of pulse doppler radar technology. The principle is based on the electromagnetic detection of a moving body through its speed rather than through its position. So the ground clutter can be totally suppressed and the moving target is always detected even in a ground skimming flight. There are several consequences:

- This technology led to the airborne warning radars li'e the AWACS (Airborne Warning And Control System). If these radars are properly positioned and operated, the air defense network can now enjoy the complete low level situation.

- The new generation fighters (F15, F16, F18, MIRAGE 2000) are equipped with pulse doppler radars and therefore are able to engage the enemy aircraft flying at low level. They can shoot

them downwards thanks to new missiles with pulse doppler seekers (AIM 7F SPARROW, MATRA S530 D, AIM 120 AMRAAM). This is the look down/shoot down capability.

- The radars associated with the SAM's can now scan in close proximity to the ground without any detection problem but the ones due to the relief screens. This quality coupled with the new missiles performances gives to the modern system a high kill probability.

Consequently the modern fighter aircraft, if they want to survive and be effective, must have:

- sophisticated ECM,
- the look down/shoot down capability.

3.4- Multi aircraft /multi target environment

The main characteristics of air power are flexibility and ability to concentrate assets in space and time. For these reasons and because of the tactical advantage brought by the mutual support in air combat, the history of aerial warfare shows a frequent use of big raids with numerous aircraft (with or without protection), these raids being countered by an air defense using itself a great number of interceptors, thus resulting in huge aerial fights. In that respect, WW2 is typical (battle of England, bombing campaigns over Germany).

In modern aerial warfare these principles are still appropriate and even more emphasized because of two reasons:

- It is now necessary to organize the raid and to assemble all the necessary types or versions of aircraft required by the

different tasks (the classic tactical ones and the new ones due to the technology) such as:

-air-to ground attackers

-CAP (combat air patrols) preceeding the raid and "cleaning the sky"

-aerial protections

-SEAD

-ECM

-sometimes RECCE (reconnaissance) aircraft just after the raid

-even AEW (airborne early warning) aircraft in the rear.

- With the advent on fighter aircraft of the long range airborne radars and the associated air-to-air mmissiles, the pilots are now concerned by friendly and enemy aircraft at greater distances than before. For instance:

-in frontal situation, a well trained modern fighter pilot feels concerned by every aircraft closing within 60 nautical miles of his present position;

-it is not unusal that two fighter pilots flying third generation aircraft regard themselves as constituting a patrol with mutual support if they fly wthin 10 miles of each other.

Consequently the modern air combat environment is characterized, more than ever, by a multi-aircraft /multi-target situation. Hence the radar and the weapon system of the fighter must have a multi-tracking/ multi-missile launch capability. This tendancy is fully consistent with the new "launch and leave"

concepts brought by some new missile technology developments such as the strap-down inertial navigation system (INS) and the active EM seeker (AIM 54 PHOENIX, AIM 120 AMRAAM, MATRA MICA)

3.5-Identification

The combination of three of the new air combat trends that we have seen before -the great missile effectiveness in a broad spectrum of ranges, the complexity of the situation, and the multi-aircraft/multi-target environment- has led to a very deep identification problem.

The current identification system, based on interrogation/response by coded electro-magnetic pulses, is called the "identification friend or foe" (IFF) upgraded by the improved coding technics of the "selective identification feature" (SIF). Unfortunately, the negative identification (absence of adequate response) by the IFF/SIF is not 100% reliable for many reasons: density of the electro-magnetic environment, jamming, forgetting to comply with the code duty chart.

The problem is particularly tough in the European theater because :

- in case of war in Central Europe, the operations will be probably of the highest possible complexity and density;
- the NATO countries have not agreed on a common IFF system; the most advanced system is the IFF Mark 12 (with mode 4), but it has not been adopted by all the Air Forces and the other systems are sometimes not compatible.

The situation is worrying to the point that a NATO survey of the problem predicts that, in case of war in Central Europe, the NATO forces would have 1 on 5 of their lost aircraft due to their own air defenses. (8)

The problem could be at least partly solved by the adoption of a new advanced system called NIS (NATO identification system) or as a consequence of the adoption of the JTIDS. But here again a common decision is not likely to be reached quickly.

The identification problem has led to a controversial debate between the supporters of the long range missiles coupled with an EM identification system ("beyond the visual range" or BVR concept) and those who think that the only reliable identification is the visual one ("visual identification" or VID concept) leading to a short range combat.

An intermediate position could be found with the advent of some new electro-optical devices (like the TISEO) wich could increase the VID range.

Whatever the solution(s) for the future, it is certain that the next generation air superiority fighters will rely heavily on identification devices built in their weapon systems.

3.6- Importance of ECM an ' ECCM

Since the Viet-Nam war, the role of electronic warfare in aerial engagements has been continuously growing. A great part of the fighter aircraft weapon system is now devoted to:

- ECM equipments for different frequencies and modulations, each of them capable of sophisticated jamming sequences,

- ECCM devices built in the onboard radar and the EM seekers of the missiles,

- ECCM interface equipments between the radar and the missiles,

- ECM/ECCM compatibility equipments to avoid that the weapon system ... jams its own equipments.

In a modern air combat environment, the threat of electro-magnetic aggression by the enemy is so high and the necessity to counter this aggression is so vital that we can argue:

"Going to modern air war without any ECM/ECCM is like going to fight without any weapon". (9)

And specially when trying to defeat a missile, a good ECM system is probably more useful than the ability to perform tight maneuvers.

3.7-Situation awareness. Total combat

The modern fighter pilot is not only responsible for piloting skilfully his aircraft (which is now relatively easy thanks to the fly-by-wire system, as we have seen before), but he has to carry out at the same time many important tasks:

- to make the most of the informations coming from the radar, the other sensors and the air defense control center (through radio or data link) in order to assess the positions and the relative movements of the threats and of the friendly aircraft.

- to try to understand "who is who" and "who is doing what" through the identification systems, the radio and...his own smartness when operating the weapon system.

- to fight the electronic war through the ECM and ECCM equipments, and to face the ensuing degradation of the detection and the radio transmissions.

- in spite of everything...to try to keep quiet and take the best tactical decisions for himself and (if he is a leader) for his wingmen.

- to maneuver in order to catch the enemy aircraft in the "missile envelopes", while at the same time avoiding the enemy missile envelopes.

- to operate the weapon system in order to launch the missiles...after having made sure they were locked on the good targets.

- if necessary, to fight the short range combat (or "dogfight") by trying to keep clear ideas under G's stress and to always relate the situation to a tactical well known case with a good solution.

Facing the high level of complexity of this situation, the modern air combat experts have greatly emphasized that the main quality for a fighter pilot is his ability to master the situation.

The key words are: "Situation awareness"

And this " situation awareness " will come essentially from the elements given by the weapon system to the pilot. Therefore we must stress the importance of the fighter aircraft cockpit conception, and of a good pilot/weapon system interface. And, in order to achieve that, we believe that the Air Force combat

experts should be involved as early as possible in the conception and development phases of the aircraft and its weapon system .

Another essential modern concept is the air-to-air "Total combat", as opposed to the short-sighted view of the only dogfight. In the "Total combat" the pilot must show his ability:(10)

- to fight at long range, then at short range, then in dogfight if necessary, then at long range again.
- to fight half looking to the radar/half visual.
- to launch a missile then fight quickly with the guns then revert to the missiles.
- to attack and at the same time protect himself with ECM.
- to fight half "head up"/ half "head down".

And to do all these tricky things the pilot must be helped by (and not fight against...) a computerized weapon system which brings him all the necessary informations and solutions on well designed displays.

4. REQUIREMENTS FOR THE FUTURE

4.1- The offensive/defensive balance

The history of war technology shows that the progress has always caused temporary shifts between offense and defense depending on whether the last improvement was for the "sword" or for the "shield".

Currently it is evident that the air combat is in the offense advantage phase. In the paragraph 3.2 we saw that the modern all aspect IR missiles will be the essential lethal threat for the fighter aircraft of the 90's.

So if we do not want to see all our expensive fighters either destroyed in an air combat or grounded by fear of destruction, there is an absolute necessity to develop for these fighters an effective IR missile defense system.

The researches can be done in two fields:

- passive characteristics:

The principle consists of reducing the IR emissions of the aircraft. This is a part of the stealth technologies.

These improvements are very expensive, because they deal with the airframe and the engine exhausts, and are not that effective against the highly sensitive modern IR seekers.

- active systems:

The idea is to aim a laser emitting system in the direction of the adversary. The purpose of this laser is not to burn the IR sensor of the seeker (it requires too much power and can be easily countered by an auto-darkening IR dome), but to jam this IR seeker with a modulated laser emission. (11)

So we argue that a high level of reseach and development should be funded in the technologies necessary for a laser IR jamming system: proper laser fitting with the mission, modulation jamming effectiveness, opto-electronic and IR tracking.

This field is probably vital for the future.

4.2-New engines

During the past decade some very important improvements have been made in the military jet engines technology: turbine blades able to work at very high temperatures, double fan jet engines

with high thrust and afterburner, high compression ratios, transsonic nozzles, excellent thrust to weight ratios.

So the performances of the fighter aircraft engines have dramatically increased and we can foresee three important fields of improvement for the next generation: (12)

- ability to cruise at supersonic speed without afterburner, wich had always been impossible before and will give to the sustained supersonic cruise an affordable comsumption;
- high acceleration capabilities and good supersonic sustained turn rates due to a very high thrust to weight ratio;
- low subsonic comsumption giving to the aircraft a significant improvement in range or combat radius.

4.3- Maneuverability in question

Several air combat surveys, based on simulations and real flights, have shown that two kinds of turning performances are important: (13)

- the subsonic instantaneous turn rate for short range combat,
- the supersonic sustained turn rate for long range combat.

In paragraph 3.1 we saw that the fly-by-wire technology has given to the fighter aircraft of the current generation a tremendous subsonic instantaneous turn rate. This is probably the limit wich is possible to reach with the "classic aerodynamic design". Going beyond would require to develop and produce some new costly technologies:

- super-stalling wich aims at controlling the aircraft when flying at very high angles of attack (40 deg to 70 deg) for aiming purpose;

- thrust vectoring in combat (like the AV8 HARRIER, but without the range and armement loading limitations inherent to its conception);

- sideforce maneuvers (developed on the F16 AFTI) wich are now possible by fitting special control surfaces on the aircraft, coupled with a specific computer.

But all these new maneuvering technologies will lead to turns exceeding 9 G's or to desorientating movements, and the question of human limits is now raised.

Lastly, apart from the cost and the pilot tolerance problems, the new trend to begin the combat at larger distances shifts the interest from the subsonic instantaneous turn rate to the supersonic turn rates:

-the supersonic sustained turn rate for a good positioning in BVR attacks and for survivability;

-the supersonic instantaneous turn rate for a hard turn after a long range missile launching in order to avoid the missile enveloppe of the enemy (this must be coupled with a good re-acceleration after the turn to distance the enemy missile).

These good supersonic performances are more a matter of thrust than a problem of aerodynamic design, and are reachable with classical airframe solutions.

4.4- <u>STOL capabilities</u>

With the development of the runway breaking munitions (such as the French BAP 100 and DURANDAL), all the Air Forces must now consider that, in case of war, they would have to operate from partly destroyed runways.

Specific surveys on this subject, based on statistic runway attack results, show that the most common case is illustrated by a NATO standard runway of 8000 feet struck in 3 places by the enemy, thus having at least a 2000 feet long piece for operations. These conditions require what is called "Short take off and landing" (STOL) capabilities. (14)

The current generation of fighters has the required performances to take off in 2000 feet (at least in air superiority configurations). But all the difficulty rests in landing in that distance. So in the future, if we want to avoid the costly and limitating solution of the HARRIER (and even of a limited thrust vectoring), we have to envision to use only reversing nozzles and develop such new technologies as :

- fast response engines for accurate control of the approach parameters,
- very low approach and landing speeds,
- a weapon system with a special display for accurate impact point performance,
- an excellent computerized braking system (with a complementary drag chute if space is allowed in the aircraft).

4.5- <u>New trends</u>

Some other important new trends are emerging now with a possible impact on the year 2000 air superiority fighter:

- a real all weather 24 hours a day capability.

- an onboard radar wich can be multi-function, multi-mode, multi-range, multi-tracking and multi-target.

- the coupling of the weapon system with the fly-by-wire system.

- the real boom on the conception of advanced cockpits (new display technologies and symbologies, accessible softwares, hands on throttle and stick -HOTAS- concept, voice control, helmet sights and displays).

- the use of artificial intelligence for advanced avionics and optimum computerized solutions.

- emergence of the concept of "fault tolerant systems" (the system compensates in case of loss of one of its elements and can work without serious degradation). (15)

- with the advent of the VHSIC technologies (very high speed integrated circuits) and the new rocket engines, emergence of a light weight (though highly performing) missile concept, enabling to carry more air-to air missiles with less drag.

All these trends involve the weapon system and the armement of the aircraft; they require to fund some substancial research and development efforts. For instance the weapon system of the ATF will be a "software intensive VHSIC system", and an important research effort is made to develop a new Integrated Communication and Navigation Architecture (ICNA). (16)

Some other trends involve basically the airframe but require only improvements and not revolutionary technologies.

They are:

- the high level of sustainability and maintainability.

- the emphasis on range, autonomy, air refueling and accurate inertial navigation systems (Falklands war).

- the advent of composite materials in building airframes.

- the impact of chemical warfare on aircraft equipments conception.

5. THE COST PROBLEMS

The problems associated with the tremendous rising of the military materials cost have already been discussed in paragraph 1.2. Some complementary points need only to be exposed:

- The cost rising for the military materials is by far superior to the inflation rate. This acknowledges the fact that there is a real improvement in the quality and the effectiveness of these materials, due to the new technoloies. But unfortunately there are too a lot of overcharging by the contractors.

- An adequate contracting can limit the cost rising, especially in the development field where the contractor must be financially accountable for the delays and the cost overstepping (financial risk).

- The quality -quantity debate has led the quantity defenders to build a " lightweight fighter " concept, the best example of wich being the "cheap" F16 (as opposed to the "expensive" F15). Moreover, based on some previous bad results of the EM air-to-air missiles, the quantity defenders tend to eliminate this type of missile. These conclusions show the bad knowledge of some debaters, and that they are not aware of the following facts:

-The "cheap fighters" lack always something; therefore their effectiveness and their survivability are

questionable.

-The ability to operate in adverse weather and at night is very important in the European theater.

-An important number of cheap fighters would create a problem of manpower to pilot and maintain the aircraft, and the pilots losses due to the poor survivability would quickly ground the remaining aircraft.

-Operating too many aircraft would create a beddown problem because the number of available bases in Central Europe is limited and there are not enough shelters or ramp space to be used.

-The cheap lightweight airplane is a false attractive solution. In fact the technology will decrease the operating cost of an ATF type airplane: more effectiveness, more reliability and more maintainability. The life cycle cost is the real parameter and much more important than the initial purchase cost.

-However numbers do count: several simulation surveys have shown that the advantage brought by a difference in technology decreases when the number of aircraft involved in the fight increases. Therefore a lightweight fighter solution can be envisioned, but only as a complementary airplane being used in conjunction with the ATF type airplane. (17)

-Making a judgment on the EM missiles based on passed poor results is wrong because it forgets the last technological evolutions: increased effectiveness, inertial/active guiding technologies, look down/shoot

down capabilities.

- In a medium size country like France, it is specially important to make the right technology choices and try to limit the cost rising for two reasons:

  - a too expensive aircraft cannot be afforded by the Air Force budget;
  - an expensive aircraft will be difficult to export, and exporting is a necessity to maintain the prices at a reasonable level (so we have a vicious circle) and to preserve the national aerospace industry.

- Research and development fundings should not be cut (in favor of a current program) each time there are some financial problems. Unfortunately there is a tendancy at the decision levels to have a short term rather than a long term policy.

- The Falkland war has shown that in modern air operations there is a tremendous consumption rate of high value munitions (especially missiles). And unfortunately the munitions stocks are very often among the first affected by the finantial problems. So it is not exagerated to assume that, after a few days of a general war, the shortages in missiles on both sides will be so big that many fights will have to be conducted with guns.This means:

  - that the fighter must be equipped with guns.
  - that the maneuverability to win a dogfight must be preserved.

6- PRIORITIES FOR THE BEST INVESTMENT

6.1- Assessing the situation

First of all we have seen that the fighter aircraft business is pinned down to advanced technology. the quality of the new soviet equipments and of the people manning them compel the Air Force of the western industrialized countries to commit themselves more and more in the technology race.

But, because of the cost rising and the budget constraints, it is no longer possible to fund new aircraft fitted with the best available technology in all the fields at once. Choices have to be made corresponding to the foreseeable situation.

In the previous chapters we have analyzed this situation. Its main characteristics are:

- the high level of complexity of the situation and the absolute necessity of the "situation awareness"
- the requirement for operational flexibility
- the highly electronic and computerized environment (detection, data processing, integration, identification, electronic warfare)
- an air combat ruled by the exceptional effectiveness of the missiles.

Although there is still an obvious requirement for good performances of the aircraft (and specially good acceleration capabilities and good turning performances), it is evident that there is a clear tendancy to shift the interest towards the weapon systems and armaments.

6.2- <u>The aircraft itself</u>

In that field we have to consider the main question: is it still necessary to increase again the maneuverability of the future aircraft ? We have seen that, due to the fly-by-wire technology, the current maneuverability reaches the highest level consistent with a "classical" aerodynamic design. Going beyond that level would be very costly by leading to new developments (super-stalling, thrust vectoring, sideforces maneuvers). And reaching the human limits to the G's tolerance would probably constrain to modify deeply the cockpit, thus the entire aircraft.

The next question is: why do we want the fighter aircraft to be highly maneuverable? Basically the answer is:

- to reach a position of advantage over the oponent aircraft,
- for aiming purpose.

Both of these reasons are no longer justified if you rely on a highly maneuverable, all aspects, very effective air-to-air missile. In other words it is probably much cheaper to give the necessary agility to the armament rather than to the aircraft.

Of course this concept is limited by the fact that you must always perserve a sufficient level of aircraft maneverability in case of loss of armament effectiveness due to successful countermeasures from the oponent, or in case of missile shortage. The aircraft must always keep a reasonable ability to win a gun dogfight style engagement.

But clearly we think that the expenses for the aircraft itself should be at least partly limited in favor of the armament, and should be directed in two basic directions:

- improvements in engine technology to reach the goals of supersonic cruising speed without afterburner, high acceleration capabilities and good supersonic sustained turn ratio.
- improvements in STOL capabilities.

6.3- The weapon system

The situation assesment has made clear that the weapon system design of the next generation fighters will be absolutely essential in the survivability and the effectiveness of the aircraft. The air superiority fighter pilot of the year 2000 will be surrounded by a world of onboard computers, multi function displays, sensors, identification devices, ECM and ECCM. All these equipments will be indispensable for the situation awareness and control which are required to win a modern air combat.

The greatest expenses in that field will have to be funded for the airborne radar and, as we have seen before, for an effective active defense system against the air-to-air missiles.

Furthermore the weapon system is probably the field where, given a good hardware design and a sufficient onboard computer power at the beginning, the improvements are the cheapest because they affect basically software modifications.

6.4- The armament

We have seen that the air-to-air missiles are probably the most effective way of winning the future air combats. Furthermore the missiles have a great potential for future developments.These developments must be funded because in the decade to came the level reached in the air-to-air missile technology will probably make the difference between victory and defeat.

Moreover it seems necessary to promote the concept of designing the aircraft through the armaments that we intend to use, rather than building first these aircraft and then trying to adapt the armaments to them.

6.5- An answer to the question

Unfortunately the day is at hand when we have to make drastic choices for the funding of the next generation air superiority fighter of the year 2000.

For all the reasons explained before in that paper, it appears very clearly that the order of funding priorities should be:

1. the armament
2. the weapon system
3. the aircraft itself

Nevertheless this concept must not be too rigid because of the possible quick evolution of the situation and the ensuing required flexibility of aerospace designs.

We must never forget that , in every Air Force, nobody knows what will be the next earial war you will have to wage.

Consequently we must add to our choice for the basic priorities the following directives:

- a sufficient level of research must be assured in each of the three fields;

- research and development fundings must be increased and must not be cut each time new financial constraints appear; we must not be too much short-sighted;

- simulations are essential and should be developed in each of the three fields in order to constantly monitor the various trends in aerial combat.

CHAPTER 1 (pages 1-5)

1. This estimation, used by the French Air Force planners, is confirmed in the book of Walter Kross, Military Reform, The High-Tech Debate in Tactical Air Forces. (Washington, DC: National Defense University Press, 1985), Figure 3-8.

2. Ibid., pp. 45-46.

3. Ratios given by a NATO General officer in a lecture to the Air War College in 1986.

4. Interview with Colonel Bedarf, HQ USAF, Directorate of Operational Requirements, AF/RDQT, Tactical Aircraft Division, 21 and 22 April 1986.

5. Study made in 1985 for a seminar of the Air War College by Colonel Bodie Bodenheim, USAF, and the author.

6. Teaching statement made often by the instructor pilots of the Aggressor Squadron based in Alconbury (Great-Britain) during an exchange with the 5th Fighter Wing of the French Air Force ,Orange AFB (France), 1979.

7. This is a strong opinion of the author and was shared by Col Bedarf during the 21 and 22 April interview, and by Col Piccirillo, Wright-Patterson AFB, Aeronautical Systems Division of Air Force Systems Command, ASD/TAS, Advanced Tactical Fighter System Program Office, during an interview, 24 April 1986. Both officers added that the air-to-air HARM type missiles (guided on the emission of the airborne radar of the enemy fighter) will be another important threat for the future fighters.

8. Survey stated by a NATO officer in a lecture to the Air War College in 1986.

9. Statement of the author used by him for development and operational motivation during the military experimentation of the Mirage 2000 in Mont-de-Marsan AFB (France), 1983-84.

10. Expression invented by the author to develop the tactical skills of the pilots when he was Squadron Commander in Orange AFB (France), and used by him when writing tactics books now published in the French Air Force.

11. This idea was given to the author by French missile engineers and shared by Col. Bedarf (21 and 22 April interview) and Col. Piccirillo (24 April interview).

12. Ibid. Interviews.

13. Surveys presented to the AGARD symposium on "Combat Maneuverability" held in Florence (Italy) in October 1981.

14. Surveys made by the French Air Force and leading to the same basic numbers as the ones used by other NATO countries.

15. Col. Bedarf and Col. Piccirillo (21, 22 and 24 April interviews).

16. Ibid.

17. Surveys also presented to the AGARD symposium on "Combat Maneuverability".

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